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REDUCTION IN NUMBER OF AIRBORNE BACTERIA BY AIR CLEANING DEVICES IN A CLOSED SPACE

by

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ABSTRACT

A need for reducing the concentration of microorganisms in the air of dental operatories has been assumed. The purpose of this study was to evaluate the effectiveness of two methods of air cleaning in reducing the number of airborne bacteria in a closed space. Tests for clearance of Bacillus subtilis spores from static and dynamic aerosols were conducted in a 700 ft^3 experimental room. The air cleaning devices were a portable electronic air cleaner with a capacity of 175 cfm (tested in combinations of one, two, and three) and a high efficiency particulate air (HEPA) filter module with a capacity of 800 cfm (tested singly and as a pair). Both devices cleaned and circulated room air only. The time required for complete clearance of spores from a static aerosol decreased as air capacity increased, from an average of 19 minutes at 175 cfm to 8 minutes at 800 cfm. With forced ventilation at 800 cfm, an average of 5 minutes was required. When a dynamic aerosol was disseminated over a 10-minute period, spore concentrations plateaued after several minutes, the level depending on the rate of air flow through the cleaning devices. Cleaning efficiency was maximum when the theoretical turnover of room air occurred once every 1 1/2 to 2 minutes. No difference was observed between the efficiency of the electronic and HEPA devices. Forced ventilation at 800 cfm produced results comparable to those of HEPA filtration at the same rate.

INTRODUCTION

The studies by Bourdillon, Lidwell, and Lovelock[1] during the 1940's provided impetus for numerous investigations relative to the aerobiology of hospital environments. As a result, sanitary control of air in hospitals, particularly in surgical operating suites, has gained widespread acceptance in programs for the prevention of infection.

Interest in dental aerobiology followed the introduction of high-speed rotary and ultrasonic instruments to dental practice. With these instruments, contaminated water sprays are disseminated in greater quantities than before, and there is little doubt that microbial concentrations in the air of dental operatories have increased.[2-5] Micik et al.[6] found that a number of dental procedures employing water sprays and rotary instruments disseminated aerosols with bacterial concentrations greater than those associated with coughing or sneezing. Because there is strong evidence that a number of diseases can be transmitted by the airborne route,[7] questions have been raised about potential dangers from the microbial concentrations in dental operatories. Because a precise relationship between air contamination and transmission of infection in the dental operatory has not been established by epidemiological studies, it can only be assumed that a reduction in the number of airborne microorganisms is desirable. In this respect, it has been found that ventilation per se can be satisfactory when the air available for intake does not add appreciably to bacterial contamination.[8] Without a source of clean air or in a closed system such as a submerged submarine, ventilation is not feasible. In such cases it would be worthwhile to evaluate the efficacy of air cleaning in reducing microbial contamination.

The purpose of this investigation was to measure the effectiveness of two methods of air cleaning in reducing the concentration of airborne bacteria in a closed space.

MATERIALS AND METHODS

All tests were conducted, under existing conditions of temperature and humidity, in a 700 ft^3 experimental room specially constructed for aerosol studies.[9] The types of air cleaning devices tested were (1) a high efficiency particulate air (HEPA) filter module,* which has a capacity of 800 cfm and is equipped with a final filter that is 99.97 percent effective in removing airborne particles 0.3 micron in size and larger and (2) a portable electronic air cleaner,† which has a capacity of 175 cfm and removes airborne particles by electrostatic

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The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

*Model 43X, Agnew-Higgins, Inc., Garden Grove, Calif.

†Model F38, Honeywell, Inc., Minneapolis, Minn.

precipitation. In all tests, but not in comparative ventilation studies, the devices were placed in the room and the room was sealed so that only room air was cleaned and circulated.

Suspensions of Bacillus subtilis var. niger (globigii) in sterile distilled water were disseminated at a rate of 3 ml/minute from a Chicago atomizer[10] placed in the center of the room, 30 inches above the floor. Previous tests had indicated that 85 percent of the viable particles recovered would be in the 1 to 5 micron range. During dissemination a 15-inch oscillating fan was run to stir the room air.

A 1-hour air sampler* was used to sample the room air during the tests. It was located just outside the room, 6 inches from the floor. The sampler was fitted with a straight, 2-foot-long polyvinyl tube, with an inside diameter of 3/4 inch, extending into the room through the wall; it was adjusted to draw air at the rate of 1 ft^3/minute. The sampler was activated immediately before dissemination of the spores and was run throughout each test period. Spores impacted on trypticase soy agar were counted in 1-minute increments after the plates had been incubated for 24 hours at 37° C. Each colony was assumed to represent a single viable particle (VP).

The effectiveness of the air cleaning devices was studied with two types of aerosols: static and dynamic.

STATIC AEROSOLS.--A suspension of B. subtilis in water (about 10^5 spores/ml) was disseminated for 1 minute, and the air in the room was allowed to stabilize. The aerosol then reached a concentration that resulted in the recovery of approximately 100 VP/ft . The cleaning device was turned on immediately after this; and the time required to clear the room of all viable particles, i.e., to reach zero recovery on the sampling plates, was ascertained. The HEPA filter module was tested as a single unit; the electronic air cleaners were tested singly and in combinations of two and three.

For purposes of comparison, clearance of static aerosols from the room by ventilation was also studied. This was accomplished by disseminating the suspension of B. subtilis spores in the same manner and then exhausting air from the room through a HEPA filter module while replacing it with fresh air drawn through an aperture in the ceiling. This provided a ventilation rate of 800 cfm, i.e., the capacity of the HEPA module. Nonpassage of spores through the HEPA filter was tested by sampling air exhausted through it. Plates of the type used in the sampler were held by hand 12 inches in front of the unit for 1 minute.

DYNAMIC AEROSOLS.--The capacity of the air cleaning devices to handle dynamic aerosols was evaluated by disseminating suspensions of B. subtilis spores continuously for 10 minutes and at the same time operating the device

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*Reyniers sampler, Model FD-100, Reyniers and Son, Chicago, Ill.

that was being tested. Before each test the spore suspension to be used in that test was disseminated for 1 minute in order to establish a value with which to compare the test result. The room air was allowed to stabilize, and the subsequent peak 1-minute viable particle recovery was arbitrarily given a 100-percent value. Spore suspensions were disseminated in concentrations that resulted in peak 1-minute recoveries of approximately 50, 100, and 200 VP/ft^3. After each preliminary 1-minute dissemination, the room was cleared of viable particles by filtering the air through a HEPA filter module. The same spore suspension was then disseminated continuously for 10 minutes. The air cleaning device under study was operated during this test period, and the changes in bacterial concentration per minute were related to the 100-percent value. The HEPA filter module was tested singly and in a combination of two; the electronic air cleaner was tested singly and in combinations of two and three.

Also measured was the clearance of dynamic aerosols from the air by a conventional room air conditioner,* which had a capacity of 450 cfm and was equipped with a low efficiency rough filter. The air conditioner, like the cleaning devices under study, was placed in the sealed room and filtered and circulated room air only. A comparison was also made of the effect of HEPA filtration and ventilation (see "STATIC AEROSOLS").

RESULTS

Table 1 shows the time required to reach zero recovery of viable particles from a static aerosol when different procedures were used. One electronic cleaning

Table 1.--Time required for clearance of static bacterial aerosols from experimental room by air cleaning and by ventilation

Procedure	Number of tests	Clearance time (minutes)
Electrostatic precipitation		
One unit (175 cfm)	14	19 ± 2*
Two units (350 cfm)	18	11 ± 2
Three units (525 cfm)	6	9 ± 1
HEPA filtration		
One unit (800 cfm)	6	8 ± 2
Ventilation		
One unit (800 cfm)	7	5 ± 1

*Standard deviation

*Chrysler Airtemp, Model H18-93, Chrysler Corp., Dayton, Ohio.

device with a capacity of 175 cfm, cleaning and circulating room air only, required a mean time of 19 minutes to effect zero recovery. The time was reduced as the air flow rate was doubled and tripled. Zero recovery was reached in a mean time of 8 minutes with a HEPA filter module at 800 cfm. In the ventilation studies at the 800 cfm rate, 5 minutes was required to reach zero recovery of B. subtilis spores from the room air exhausted through the HEPA filter module.

Table 2 shows the recovery of viable particles from dynamic aerosols disseminated while the air cleaning devices under study were operating. The recovery values are expressed as percentages of the preliminary peak 1-minute concentrations of viable particles. Each value listed represents the mean of three tests: one for each of the three spore suspensions.

Table 2.--Percentage recovery of viable particles (VP) from dynamic aerosols by an air conditioner and the air cleaning devices tested, during each minute of test periods

Air cleaning device	Recovery of viable particles (percent)*									
	Time (minutes)									
	1	2	3	4	5	6	7	8	9	10
Air conditioner										
One unit (450 cfm)	43	-	135	-	210	-	330	-	-	394
Electronic air cleaner										
One unit (175 cfm)	50	97	122	149	170	179	166	187	193	192
Two units (350 cfm)	25	60	73	100	106	91	103	102	106	98
Three units (525 cfm)	16	52	80	80	74	72	71	77	75	75
HEPA filter module										
One unit (800 cfm)	31	64	72	67	75	72	73	73	77	77
Two units (1,600 cfm)	15	39	39	43	42	31	31	39	45	37

*Values are expressed as percentages of peak 1-minute recoveries from corresponding static aerosols of approximately 50, 100, and 200 VP/ft^3. Each value represents a mean of one each of the three.

With the air conditioner the viable particle recovery counts continued to increase throughout the test period; but with the other devices, the counts reached a plateau, where they remained for the rest of the period. These plateaus may be noted in Figure 1, which shows curves taken from the data in Table 2. No practical difference was observed between the recovery values for the three electronic cleaning devices at a total of 525 cfm and one HEPA filter module at 800 cfm. At 10 minutes these values were approximately 80 percent less than those for the air conditioner; with two HEPA filter modules at 1,600 cfm the recovery values were approximately 90 percent less.

Figure 2 shows curves based on data obtained from HEPA filtration and forced ventilation of dynamic aerosols. A HEPA filter module at 800 cfm gave approximately the same results when it filtered room air as it did when it was used only to ventilate the room.

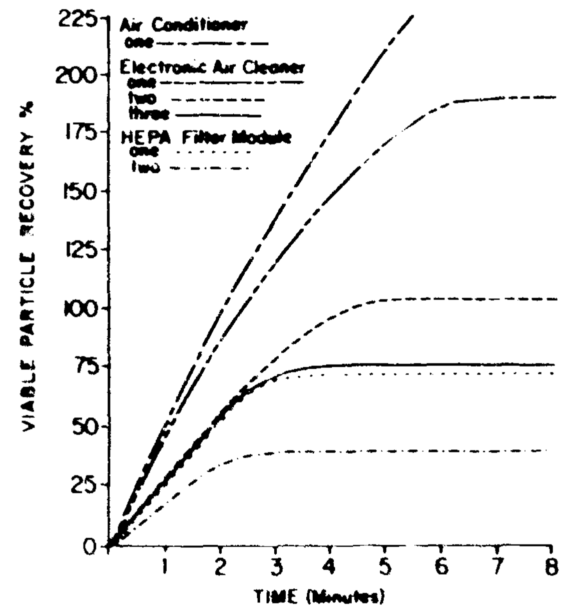

Fig. 1. Percentage recovery of viable particles from dynamic aerosols by an air conditioner and the air cleaning devices tested. Values are expressed as percentages of peak 1-minute recoveries from corresponding static aerosols of approximately 50, 100, and 200 VP/ft^3. Each value represents a mean of one each of the three.

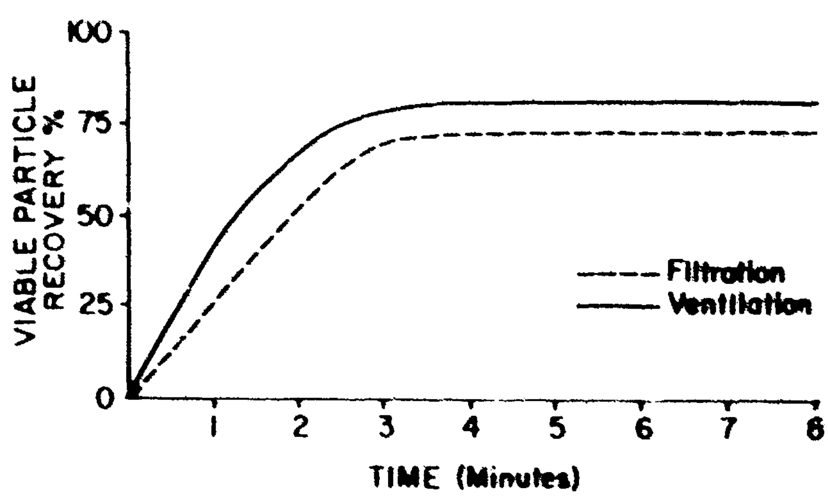

Fig. 2. Comparative effect on viable particle recovery from dynamic aerosols when HEPA filtration and ventilation were used at same flow rate of 800 cfm.

DISCUSSION

This study shows that air cleaning by either electrostatic precipitation or HEPA filtration is effective for reducing concentrations of airborne bacteria in static or dynamic aerosols. The cleaning effectiveness, with respect to particle size, of the electronic cleaners used in this study is unknown, but it appears to be comparable to that of the HEPA filters. The rough filter in the air conditioner was ineffective for particles of the size used in this study.

As can be seen in Table 1 and Figure 1, cleaning effectiveness was closely related to flow rate. Three electronic cleaners having a total capacity of 525 cfm produced results similar to those obtained with a HEPA filter module having a capacity of 800 cfm. In the experimental room, with a volume of 700 ft^3, maximum air cleaning efficiency appeared to be attained between 350 and 525 cfm. This suggests that maximum efficiency may be achieved when the ratio of room volume to air flow rate is approximately 1 1/2:1 to 2:1 (a theoretical turnover of room air once every 1 1/2 to 2 minutes).

Of particular interest in this study is the evidence that air cleaning devices can be as effective as ventilation in clearing viable particles from room air. If fresh, clean intake air is available and exhaust air is of no concern, ventilation is the method of choice in terms of cost and use of space. Such a situation exists on surface ships, where fresh air is drawn from the outside and exhausted to the outside. On the other hand, where a closed system must be used, either electrostatic precipitation or HEPA filtration will reduce the concentration of airborne bacteria. Individual operating requirements must be considered in making a choice.

The studies just reported were performed in an experimental room. It would be of great interest to ascertain the effectiveness of the air cleaning devices under clinical conditions. Such studies are now being performed.

Still unresolved is the question of what level of microbial concentration is acceptable in a dental operating room. Counts of zero to less than 1 VP/ft^3 in surgical operating suites have been suggested as being acceptable.[11] It is unlikely that similar requirements would be applied in all dental operatories. However, it would be expedient to reduce counts in rooms where dental surgery is being performed. Additionally, where certain procedures, such as scaling with an ultrasonic device, introduce organisms into the room air in many times the normal number,[5,12] something should be done to reduce the concentration. Either adequate forced ventilation or an air cleaning system such as one of the types described here is recommended.

SUMMARY

The reduction in number of airborne bacteria by two air cleaning devices in a closed space was studied. A high efficiency particulate air filter and an

electronic air cleaner were evaluated on both static and dynamic aerosols that were experimentally disseminated. Results were compared to those obtained by forced ventilation.

It was found that reductions of over 80 percent in the bacterial concentration in a closed room could be obtained using air cleaning devices with a theoretical room air turnover every 1 1/2 to 2 minutes. These devices were as effective as forced ventilation at similar rates.

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REFERENCES

1. Bourdillon, R. B.; Lidwell, O. M.; and Lovelock, J. E. Studies in Air Hygiene. Medical Research Council Special Report Series No. 262. London, His Majesty's Stationery Office, 1948.
2. Madden, R. M., and Hausler, W. J., Jr. Microbiological Comparison of Dental Handpieces. 1. Preliminary Report. J Dent Res 42:1146-1151 Sept-Oct 1963.
3. Miller, R. L.; Burton, W. E.; and Spore, R. W. Aerosols Produced by Dental Instrumentation. In Proc First Int Sympos Aerobiol. Berkeley, Calif. 1963, pp. 97-117.
4. Larato, D. C.; Ruskin, P. F.; Martin, A.; and Delanko, R. Effect of a Dental Air Turbine Drill on the Bacterial Counts in Air. J Prosth Dent 16:758-765 July-Aug 1966.
5. Larato, D. C.; Ruskin, P. F.; and Martin, A. Effect of an Ultrasonic Scaler on Bacterial Counts in Air. J Periodont 38:550-554 Nov-Dec 1967.
6. Micik, R. E.; Miller, R. L.; Mazzarella, M. A.; and Ryge, G. Studies on Dental Aerobiology: I. Bacterial Aerosols Generated During Dental Procedures. J Dent Res 48:49-56 Jan-Feb 1969.
7. Langmuir, A. D. Epidemiology of Airborne Infection. In Conference on Airborne Infection, Miami Beach, Fla., Dec 7-10, 1960, W. McDermott (Editor). Baltimore, The Williams & Wilkins Co., 1961, pp. 173-181.
8. Greene, V. W.; Bond, R. G.; and Michaelsen, G. S. Air Handling Systems Must be Planned to Reduce the Spread of Infection. Mod Hosp 95:136-144 July-Sept 1960.
9. Shreve, W. B.; Pelleu, G. B., Jr.; and Wachtel, L. W. Effect on Airborne Bacteria of Extraneous Particulate Matter or Air Filtration, NDS-TR-007. Bethesda, Md., Naval Dental School, Jan 1969.
10. Rosebury, T. Experimental Air-Borne Infection. Baltimore, The Williams & Wilkins Co., 1947, p. 80.

11. Michaelsen, G. S. Air, Its Importance and Control. In Proc, Course in Environmental Health and Safety in Medical Care Institutions. Washington, D.C., Howard University, Apr 26-30, 1965.

12. Pelleu, G. B., Jr.; Shreve, W. B.; and Wachtel, L. W. Reduction of Microbial Concentration in Air of Dental Operating Rooms by HEPA Filtration. NDS-TR-008. Bethesda, Md., Naval Dental School, Jan 1969.

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